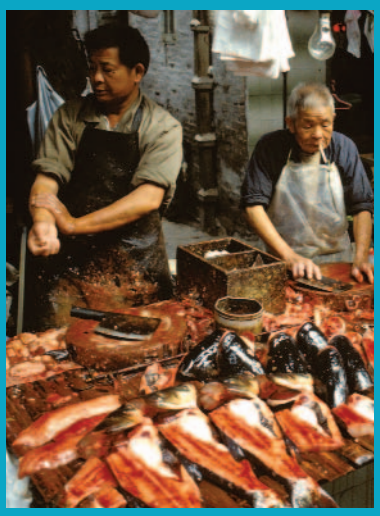
THE STATE OF THE OCEANS, PART 1

Eating Away at a Global Food Source

Consumer demand for seafood has skyrocketed since the 1970s. Total fish consumption worldwide jumped from almost 50 million metric tons in 1976 to 95.5 million metric tons in 1990, according to the 2002 *State of World Fisheries and Aquaculture* report by the Food and Agriculture Organization (FAO) of the United Nations. This does not include fish used to feed farmed fish, poultry, and other livestock, which hovers around 30 million metric tons a year. Worldwide, about 1 billion people rely on fish for at least 30% of their animal protein, according to the FAO. Some small island nations depend on fish for protein almost exclusively.



Feasting on fish. Total fish consumption worldwide reached 95.5 million metric tons by 1990.

Seafood has long been a primary source of protein, vitamins, minerals, and essential fatty acids for the world's poor. Human populations have risen significantly in many developing countries where fish consumption patterns have historically been high, says Nikolas Wada, a senior research assistant at the Washington, D.C.–based International Food Policy Research Institute (IFPRI) and coauthor of the October 2003 report *Outlook for Fish to 2020: Meeting Global Demand*. As populations become increasingly urbanized, per capita fish consumption tends to rise because of exposure to new markets and dietary patterns.

Moreover, Wada says, FAO and IFPRI studies have shown that as incomes rise, people consume more fish on average. "Since the past several decades have seen tremendous growth in the urban populations of poor countries with traditional fish diets, along with income growth in these populations," he says, "it is no surprise that fish consumption has exploded." And in wealthier nations—where heart disease, obesity, and other "diseases of affluence" run rampant—people are seeking healthier sources of animal protein.

But with this explosion in consumption has come an explosion in environmental health consequences. Among these are exhaustion of many wild fish stocks, pollution associated with aquaculture, marine habitat destruction, spread of seafood-borne diseases,

Left: Corbis; right: Mark Henley/Panos Pictures

exposure to pollutants that bioaccumulate in fish, and growing disparity between who in the world can afford to eat fish and those who cannot.

An Industry Expands

For thousands of years, most fishing vessels hugged the shorelines. Artisanal fishermen rowed and sailed through estuaries and the coastal ocean, armed with rough hooks and handmade nets. By the seventeenth century, fishermen of northern Europe and North America were beginning to travel great distances for cod and other species for national and international markets. In the nineteenth century, English fishermen began operating steam trawlers with power winches to pull up the nets, which made fishing far more efficient. Still, most small vessels remained relatively primitive up through the 1950s.

By the 1960s and 1970s, however, fishing vessels and practices throughout the Northern Hemisphere were becoming far more sophisticated. Fishermen invested in higher-powered engines, improved navigational equipment, and advanced trawling and netting gear. Between 1970 and 1990, the size of the world's decked fishing fleet—that is, vessels with a hold for storing fish—doubled from 585,000 to 1.2 million vessels, according to the FAO. During this time, many seafaring nations including the United States, Russia, most European countries, and Japan subsidized their fishing industries through billions of dollars' worth of low- or no-interest loans and payments.

Since 1990, the number of new decked vessels has stalled—so many have been built that it is cheaper to upgrade an existing vessel than build a new one—but those that are built are much larger and safer to handle on the open sea. For example, in 1980, the typical shrimp trawler in the southeastern United States was wood-hulled and 50 feet long. Now these boats may be 80–100 feet long and steel-hulled, which lets them pull faster, work in rougher waters, and catch more shrimp, which can be held in onboard freezers. In this same era, a new kind of super fishing vessel—the giant catcher-processor ship—has moved in to exploit resources even more efficiently.

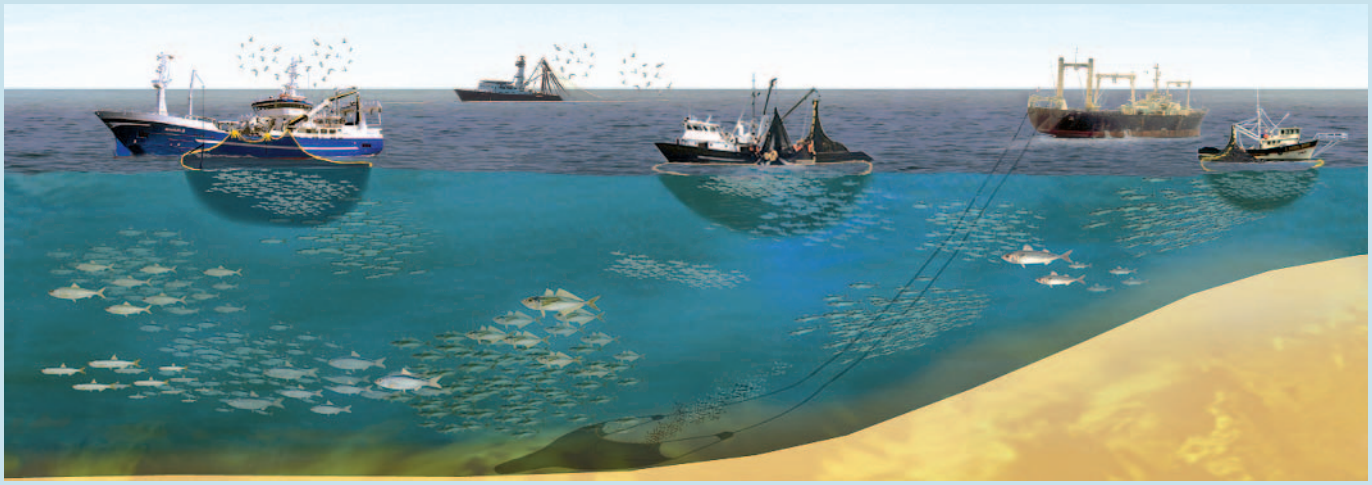
A trade redefined. Fishermen like the George's Bank crew above were once the state of the art, and many fisheries were protected by mankind's inability to reach them. Today, vessels are equipped with sonar, Global Positioning System equipment, and (near right) helicopters used to visually search for schools of fish. These tools translate in massive catching capabilities (far right).

Today, swarms of vessels are trawling the ocean bottom for fish and shrimp, setting lines and hooks for tuna and swordfish, and spreading nets to catch various other fish species in every sea in the world. With sonar, mariners can detect fish schooling in the deep ocean. Trawling vessels use depth recorders and Global Positioning System equipment to find bottom fish and crustaceans.

Not long ago, the oceans' bounty of fish seemed bottomless, an endless resource. But times have changed. "We fish everywhere now," says Daniel Pauly, a fisheries biologist at the University of British Columbia. "A hundred years ago, cod fisheries were protected by the depth and distance from the coast. Today, technology makes it possible to fish anywhere. The areas that once were refuges are gone."

Overfishing: A Chief Problem

New markets for fish and greater production of fish have influenced one another. Sometimes a delicacy becomes standard fare



Tools of the trade. Commonly seen fishing vessels in the Pacific Ocean include (left to right) the Chilean purse seiner, the tuna purse seiner, the Peruvian purse seiner, the trawler, and the small purse seiner.

Top to bottom: NMFS; M. Recabal/NOAA

relatively quickly—30 years ago, shrimp and salmon were delicacies in the U.S. Midwest, but now they are commonly eaten. Typically, upscale restaurants serve a seafood dish, and then customers ask local seafood dealers if they can get that item. Chain restaurants then respond to demand. Meanwhile, fishermen and aquaculturists see that they can make money, and they ramp up production. Over a couple of decades, if demand stays high, production surges. Very popular fish can be overexploited very quickly in this scenario.

The State of World Fisheries and Aquaculture 2002 noted that total world wild fishing for food and for use in fish oil and fish meal (including both inland and marine) jumped from almost 20 million metric tons in 1950 to almost 80 million metric tons in 1985 before growth leveled off. Fisheries scientists have pointed out the major reason for the plateau in wild harvests: once-vast populations of cod, herring, menhaden, pollock, tuna, flounder, snapper, redfish, and other valuable food species have been depleted by overfishing, which many scientists argue is by far the marine environment's most pressing problem.

Today, about 47% of commercial fish stocks worldwide are considered fully exploited, or fished at or near their maximum sustainable limits, according to *The State of World Fisheries and Aquaculture 2002*. Approximately 25% are underexploited or moderately exploited. About 28% are overfished (meaning it is likely stocks will decline further unless fishery managers reduce overfishing) or collapsed (meaning a fishery will not recover unless drastic, long-term fishing reductions are made). In the United States, about 30% of major fish stocks were overfished in 2001, according to the National Marine Fisheries Service (NMFS). European nations also overfish about 30% of their fisheries, says Michael Sissenwine, NMFS director of scientific programs.

Overfishing in many instances tends to target the largest species and the largest animals within particular species. In a study published in the 15 May 2003 issue of *Nature*, Ransom Myers, a biologist at Dalhousie University in Halifax, Canada, wrote that "the global ocean has lost more than 90% of large predatory fishes." Moreover, a fishing ground's marine carnivores can be overfished in a matter of just several years. Myers cites the example of the Gulf of Thailand, where trawling reduced the abundance of large finfish, sharks, and skates by 60% during the first five years of industrial trawl fishing from 1965 to 1970.

Innocent bystander. Fishing vessels destroy some 20 million metric tons of bycatch each year.

So-called apex predators such as swordfish, cod, tuna, and grouper are among the most valuable fish products, drawing premium prices for their taste and size. Apex predators in marine systems generally feed on smaller fish that in turn consume plankton and copepods. Removing these top predators from the marine system is disrupting the oceans' food webs, according to a report published by Pauly and colleagues in the 6 February 1998 issue of *Science*.

Once predator populations decline, fishermen then pursue smaller prey species on the next lower level of the food chain, including anchovies, squid, and jellyfish, says Pauly. Calling this "biomass extraction," the seafood industry turns the harvest of smaller creatures into products such as fish sticks, protein concentrates for livestock, and pellets to feed salmon and shrimp. Sissenwine cites other growing markets for smaller prey species: European nations including Italy, Spain, and Germany import a good deal of squid for food, and jellyfish is now considered a delicacy in Japan and Southeast Asia. In their 6 February 1998 *Science* report, Pauly and colleagues call this process "fishing down the food web."

A significant fraction of the world seafood catch never reaches consumers. Fishing vessels kill and discard huge amounts of "bycatch"—sea creatures that are caught unintentionally. Fishing

Clockwise from top left: Jose Cort/NOAA; NOAA; Bob Williams/NOAA

Mighty shrimp. The world's passion for shrimp has brought jobs and foreign income to many developing countries. Plants in South America (above) and Asia (right) produce one-quarter of this highly valuable crop.

vessels worldwide annually destroy an estimated 20 million metric tons of bycatch—about one-quarter of the global catch, according to the FAO. The amount of discard is highly variable depending on the fishery, sophistication of fishing technologies and regulations, and available markets for nontarget species.

Despite these figures, the U.S. fishing industry does not see overfishing as a pervasive problem. "Commercial fishing doesn't represent a widespread threat to the ocean," says Linda Candler, a vice president at the National Fisheries Institute, a fishing and seafood trade organization based in Arlington, Virginia. "Overfishing tends to be localized and species-specific."

Aquaculture and the Economics of Seafood

During the late 1970s, international agencies such as the World Bank began encouraging fish farming—or aquaculture—as a method of providing food for the poor and promoting economic development. Today, aquaculture provides one-third of the world's total food fish supply, and is the fastest-growing food production industry worldwide, according to *The State of World Fisheries and Aquaculture 2002*. By 2030, says the same report, aquatic farming will probably provide more than half of the fish and shellfish for human consumption.

High-value marine and brackish species, especially shrimp and salmon, hold the greatest economic clout in international seafood markets by a wide margin. About 20 years ago, new global markets for shrimp transformed the fish products trade. Shrimp has become the primary fish commodity sold worldwide, worth one-fifth of the total value of internationally traded fish products, according to the FAO. About 26% of total production of shrimp comes from coastal farms, primarily in Asia and South America. The shrimp trade has become extremely important to many developing nations, providing a source of jobs and export income.

Farmed salmon has also emerged as a force in international trade. Cultured salmon production increased from virtually zero to about 1 million metric tons in less than two decades. Norway, Chile, and the United Kingdom are major exporters, and Europe, the United States, and Japan are major consumers.

Overall, aquaculture production adds enormously to world fish supplies. Herbivorous fish and mollusks account for about 90% of the world aquaculture production. But the carnivorous species raised on some farms are, in some cases, competing with humans themselves as fish consumers. Farmers of salmon, sea bass, flounder, and other carnivorous species use high-quality wild fish protein in the form of fish meal and fish oil to grow species quickly and to enhance their flavor. (This is also true to a lesser extent of shrimp aquaculture, although shrimp require less animal protein than carnivorous fish species.)

Fish meal and fish oil are processed from small species harvested from the ocean, including menhaden from the Gulf of Mexico, Peruvian anchovies and mackerel, Icelandic herring, Norwegian capelin, sand eels from the North Sea, and sardines from West Africa. In recent years, more low-value fish species are being fed to carnivorous species in China and Southeast Asia, says Albert Tacon, an aquaculture nutritionist with the Hawaii Institute of Marine Biology. Many of these low-value species have traditionally provided relatively cheap and crucial protein for the poor in many coastal developing countries. But as the aquaculture industry demands more, the price for these fish is driven upward, and in many cases, they aren't as readily available in local markets as food for people.

Tacon further says that many small fish are handled badly and processed cheaply, which ruins their flavor and makes them useful only for animal feed. For people who rely primarily on starch diets, a small amount of fish is a crucial part of their diet. There is an urgent need, Tacon says, to make these "industrial" fish a food source for

Jeremy Horner/Panos Pictures

Competing consumers. Farmed salmon production increased from virtually zero to about 1 million metric tons in less than 20 years. Each year, farmed fish and other livestock consume about 30 million metric tons of fish.

humans rather than for livestock, and more research efforts should focus on how to properly process these fish for direct human consumption, especially in poor countries.

"If we can show the fisherman how to process industrial fish better," Tacon says, "they can make more money selling these fish for human consumption." He adds that technologies and handling techniques are becoming more available to allow fishing industries to affordably make these species more palatable to address protein needs of people.

According to *Outlook for Fish to 2020*, prices for salmon, shrimp, and other high-value fish products will likely rise 15% before inflation by 2020. The prices of low-value fish such as carp and sardines will rise 6%, and fish meal prices will jump 18% to satisfy the rising demand for farmed fish. "The people to worry about in terms of higher fish prices and lower fish availability," says Wada, "are those who live in coastal communities where fish already represents a crucial part of the diet—the west coast of Africa, the west coast of South America, the coasts of Southeast Asia and China, and the island nations."

Pollution and Habitat Loss: A Recipe for Disease

The dramatic growth in aquaculture has come with other environmental costs, as well. Some forms of marine aquaculture

Survival of the fittest? In one example of fish and humans competing for the same food, the anchovetas filling this boat (left) are destined to become fish meal (above) to feed farmed carnivorous fish.

Clockwise from top: Chris de Bode/Panos Pictures; Chris de Bode/Panos Pictures; Jose Cort/NOAA; Jose Cort/NOAA

have polluted ocean waters with fish wastes, as when farmers release large amounts of wastewater from shrimp ponds into estuaries to reduce stress on their stock, spreading disease from farm to farm. And until the early 1990s, some shrimp farmers cut down mangroves in several nations in Asia and Latin America, devastating a crucial nursery area for wild fish and shellfish.

But aquaculture is not the only factor pressuring the habitats that marine fish rely on. Worldwide, sprawling coastal cities are growing rapidly, spreading across river deltas, draining wetlands, building on floodplains, cutting coastal forests, and increasing sediment loads into estuaries and coral reefs [see "Coastal Cities: Living on the Edge," *EHP* 110:A674–A681 (2002)]. Coastal wetlands—salt marshes and tidal flats in temperate areas, and mangrove forests in tropical regions—provide food, habitat, and nurseries for as much as 90% of marine finfish and shellfish (as in the eastern United States). By disrupting these habitats, poorly planned coastal developments have reduced commercially important fish populations and spread diseases that can adversely affect human health.

Coastal nations send undocumented amounts of pollutants—sewage, persistent organic pollutants, heavy metals, oils, sediments, and nutrients—into waterways that flow into the sea. Agricultural runoff—a mixture of sediment, livestock waste, nutrients, pesticides, and fertilizers—can also reach coastal waters. The United States and most other developed countries treat domestic and industrial effluent to some degree. But raw sewage still leaks into the sea via broken and aging sewers and improperly functioning septic systems. Many developing countries, where treatment is nonexistent or inadequate, lack the funds and technical expertise to prevent domestic and industrial pollution from flowing into coastal waters.

Many polluted coastal areas have become breeding grounds for waterborne viral and bacterial diseases concentrated in shellfish, and for harmful algal blooms that can contaminate seafood. Filter-feeding shellfish, especially oysters and clams, are the most common conduit of seafood-borne illness worldwide. These shellfish feed directly on whatever bacteria come their way and also consume algae and suspended detritus containing attached bacteria and viruses. When people eat raw or undercooked shellfish, the pathogens may be passed on to the human consumer.

Marine viruses cause most of the seafood-borne illnesses worldwide. Most seafood-borne viruses probably originate from human sources, particularly fecal matter. Viral seafood-borne illnesses are not necessarily spread strictly through contaminated water. For example, Norwalk and Norwalk-like viruses, which cause gastroenteritis, are spread primarily from one infected person to another, often via food. Fishermen infected with viruses have contaminated oysters during harvests. Filter-feeding shellfish, especially oysters, also concentrate hepatitis A and E, which originate in human fecal matter.

Bacteria are the second most common source of seafood-borne illness. Bacteria that cause diseases in humans include some

Conduit for illness. Around coastal cities, especially in countries where domestic and industrial wastewater treatment may be inadequate or nonexistent, pollution can flow unchecked into water bodies, ultimately ravaging marine environments and introducing contaminants into seafood supplies.

Mark Henley/Panos Pictures

organisms (*Vibrio vulnificus* and *V. parahaemolyticus*) that live naturally in marine environments. Shellfish, especially oysters, concentrate *Vibrio* bacteria that are native to U.S. waters. In 1979, *V. vulnificus* was identified in the blood of patients with underlying liver disease who developed infections after eating raw oysters or being exposed to seawater. This bacterium is a natural summertime organism in shellfish.

Other dangerous marine bacteria originate with human and livestock waste transmitted to coastal waters via sewage outfalls, septic tanks, and land runoff. The bacteria *Listeria monocytogenes*, which causes listeriosis, and *Morganella morganii*, which causes scombroid poisoning, are carried in raw or undercooked shellfish. Symptoms in humans include chills, fever, and collapse.

Once in the water, harmful microorganisms can be drawn into ships' ballast waters and then spread from one coastal region to another, infiltrating local seafood supplies. Thus, notes a 1999 National Research Council report *From Monsoons to Microbes: Understanding the Ocean's Role in Human Health*, "The increasing demand for seafood in both industrialized and developing countries, compounded by the variety of waterborne pathogens, adds to the potential for outbreaks of disease." In 1998, a new strain of *V. parahaemolyticus* contaminated oyster beds in Galveston Bay and caused an epidemic of diarrheal illness in people who ate the oysters raw. Because the affected oyster beds were near shipping lanes, the authors of *From Monsoons to Microbes* suggest that the bacteria arrived in the ballast water of freighters and tankers coming into the harbor from distant ports.

Algal toxins cause a third major class of dangerous seafood-borne disease. Blooms of harmful algae—some known or believed to be stimulated by pollutants including nutrients in human sewage, aquaculture effluent, and runoff from agriculture and urban development—are contaminating seafood with toxins that can cause intestinal and neurological disorders, according to *From Monsoons to Microbes*. In *Oceans and Human Health*, the result of a December 2001 scientific roundtable sponsored by the NIEHS and the National Science Foundation, it is estimated that harmful algal blooms cause more than 60,000 individual cases and clusters of human intoxication annually in the United States.

One fish contaminant that has been the subject of intense media and government attention lately is mercury. Methylmercury, the organic form of mercury, bioaccumulates in fish tissue, with larger, longer-lived fish such as shark and swordfish carrying the highest amounts. According to the Agency to Toxic Substances and Disease Registry, exposure to high concentrations of methylmercury can cause permanent damage to the brain and kidneys. Methylmercury can also be passed from a mother to her unborn child, with effects including brain damage, mental retardation, incoordination, blindness, and seizures. Studies have not yet shown conclusively what, if any, concentration of methylmercury is safe for human consumption, but experts agree that the contaminant is a serious danger for the developing fetus.

Policing the Fisheries

In the United States, concerns about ocean health are being addressed by two major research and advisory commissions. In May 2003, the Pew Oceans Commission—with 18 members including fishermen, scientists, and elected officials—published a report, *America's Living Oceans: Charting a Course for Sea Change*, that called for "a serious rethinking of ocean law, informed by a new ocean ethic." After three years of study, the 16-member U.S. Commission on Ocean Policy is also expected to issue a comprehensive report addressing a wide range of ocean and coastal issues. The commission is slated to present its findings to state governors in spring 2004, and a final report is due later this year.

Under the Magnuson-Stevens Act of 1976, the U.S. Congress created eight regional councils to manage the nation's fisheries. These councils recommend limits on fishing and allocate catches among competing fishermen and fishing interests. They offer their recommendations to the NMFS and the Secretary of Commerce, who make the final determinations on fishing regulations.

Although the councils include state and federal resource managers, they were specifically set up so that the majority of votes are held by representatives from the commercial and recreational fishing industries in the expectation that such an arrangement would offer an incentive to sustain stocks over time. But this effectively puts the fishing industry in command of determining its own catch, according to the Pew report. Further, states the report, the councils have been charged with two contradictory aims: They are supposed to limit the number of fish caught so that stocks are sustained. Yet each council has the authority to allocate allowable catches within its regional fishing industry.

When a region faces conflict in deciding which groups can catch how many fish, then "the natural tendency is to increase the size of the pie," says Andrew Rosenberg, who is dean of life sciences at the University of New Hampshire, former Northeast regional administrator of the NMFS, and a member of the U.S. Commission on Ocean Policy. Instead of cutting back fishermen's access to a declining or stagnating resource, Rosenberg says, councils tend to argue that there are more fish available to catch than there really are.

Fishermen on councils tend to look at a regional fishery resource from the point of view of their own individual businesses and financial interests, says Rosenberg. After a

NASA

Blossoming blight. Harmful algal blooms, like this red tide off the coast of Texas (which appears as the dark stripe in the ocean running along the coast) are exacerbated by human activities and are believed to contribute to thousands of U.S. disease cases each year.

fishery has collapsed and regulations have been put in place to recover that resource, fish populations do commonly begin to revive over time. But too often, commercial and recreational fishing interests on councils are unwilling to sustain effective regulations long enough—perhaps as long as 10 years—to allow the population to recover fully, says Rosenberg, who adds that once a fish population begins to recover, "the fishermen say, 'We should be able to participate in getting those fish.'"

But John Mark Dean, a University of South Carolina marine scientist, says his own experience as an appointed member of the South Atlantic Fishery Management Council is much different from Rosenberg's experience in the Northeast. The South Atlantic council, which oversees fisheries in federal waters from North Carolina to the Florida Keys, strictly regulates and manages the resource for long-term conservation benefits, says Dean. In 1989–1991, the South Atlantic council established tough limits on catches of Spanish mackerel and king mackerel, both of which had declined in population, says Dean. Now those fisheries are thriving. "We've recovered fisheries, and we were precautionary in doing so," he says.

Ken Hinman, president of the National Coalition for Marine Conservation, a nonprofit organization based in Leesburg, Virginia, with a membership of 1,500 fishermen, says that some councils are significantly more conservation-minded than others. And some fishing representatives on some councils consistently push for more sustainable harvests. "You can't characterize whether a council member is good or bad for the fishery resource based on what he does for a living," says Hinman. "But I also think that people should not be voting on things in which they have a direct financial interest."

A Sea Change for the United States

The Pew report points out that ocean management decisions currently are divided among local, state, and federal agencies and tribal authorities, with little coordinating effort. As a result, some fish species swim from an area regulated by one state's natural resource agency into an area regulated by a different state's agency, then into federal waters where the NMFS has authority. Meanwhile, fish in the coastal ocean might be affected by runoff from development approved by local governments, by dredging for navigation by the U.S. Army Corps of Engineers, by nutrient pollution from livestock farms and municipal wastewater operations, and by offshore oil and gas operations. Yet in many cases, different agencies, governments, and industries do not regularly communicate with one another.

To open lines of communication between different levels and bodies of government, the Pew report argues that the government's fragmented ocean programs should be merged into a new independent federal agency, which should have more authority to manage fisheries and marine ecosystems. The report also proposes the creation of regional ecosystem management councils within the federal government. These new regional ecosystem councils would collaborate with fishery management councils and other regulatory agencies in adopting the so-called ecosystem approach—that is, managing fisheries by protecting the ecosystems they are part of.

These new ecosystem councils would provide more of a "big picture" for resource managers. Each region would determine what its own most important problems are, and work to find solutions. For example, if a major regional problem is runoff from farms and cities polluting coastal waters, the federal ecosystem management council would bring watershed managers and agriculture experts together with fishery managers to strategize on how to address the runoff and how to collaborate better with the regional fishery management council.

"We're not calling to displace the current management structures for fisheries but rather to provide a coordinating mechanism," says Christopher Mann, policy director of the Center for SeaChange, a nonprofit organization based in Arlington, Virginia. "We need to think more broadly about how to manage these areas for a variety of uses," agrees Marc J. Hershman, an ocean policy professor at the University of Washington School of Marine Affairs and a member of the U.S. Commission on Ocean Policy.

The U.S. Commission on Ocean Policy has declared that conflicting regulatory authority in the coastal and marine realm is a problem that needs to be resolved. As a result, the commission will reportedly call for new coordinating councils at the national and regional levels, to better coordinate federal policies. But these new regional councils would differ from those proposed by the Pew Oceans Commission in that the Commission on Ocean Policy will probably call for more of a "bottom-up," voluntary approach to regional councils, says Hershman. "From my own perspective, I hope that a new national council would stimulate and give encouragement and seed grants to regions that want to develop some kind of regional approach to their coastal and marine issues."

The National Fisheries Institute is skeptical about regional ecosystem management councils in any form, however. "Do we really need to add another layer of bureaucracy?" asks Candler. "It's not clear that's going to help."

In another idea for fostering wild fish populations, the Pew Oceans Commission has called for an expanded system of marine protected areas, including no-take reserves. Currently, states the report, the area of the ocean under U.S. jurisdiction protected in marine reserves—where all fishing and other disruptive activities are prohibited—is less than 1%. According to some studies, marine

U.S. Coast Guard

no-take reserves have helped restore fishery populations outside the reserves: adults and juveniles migrate outside of the reserve's borders, and currents relocate larvae. Within reserves, fish populations increase in size. Individuals also tend to live longer, grow larger, and reproduce more.

In an article in the September 2003 issue of *Trends in Ecology & Evolution*, British scientists Fiona R. Gell of the University of York and Callum M. Roberts of the Port Erin Marine Laboratory examined a body of evidence about marine reserves' effects on fishery populations outside their boundaries. "We find that well-enforced marine reserves have great potential to maintain or enhance fishery catches and increase sustainability," write Gell and Roberts. "They should be used much more widely and with more confidence in their function."

But critics argue that most commercial species are too mobile to benefit from such efforts, and that marine reserves are effective only in certain cases, such as small-scale tropical fisheries. Many U.S. fishing groups—both commercial and recreational—are opposed to implementation of significant marine reserves; however, says Candler, "We do support marine protected areas in certain places under certain conditions if it's clear that the objective of the reserves will be met and if the objective is based on sound science."

Change at the Global Level

Policy fragmentation is a problem at the global level as well, although international cooperative management efforts are growing. Most of the world's seafood is harvested within individual countries' "exclusive economic zones," which extend 230 miles offshore. Therefore, individual nations regulate the great majority of the globe's wild marine catches. A few important fisheries—including highly migratory ones such as tuna and swordfish—are regulated by international agreements, and such agreements have successfully stabilized some swordfish and salmon populations, although they have failed to recover North Atlantic redfish and cod. Many international treaties are criticized by conservationists and the fishing industry alike as inefficient and unable to control overfishing and prevent piracy of very valuable fish such as bluefin tuna.

In a fresh bid to control overfishing, the 192 nations present at the August 2002 World Summit for Sustainable Development (WSSD) agreed on ambitious targets for rebuilding overexploited fisheries by 2015. This summit agreement complements previous agreements, such as the voluntary FAO Code of Conduct for Responsible Fishing for UN member states. It also mirrors elements of the two U.S. commissions. For example, the WSSD agreement says that nations should "encourage the application of the ecosystem approach" by 2010. And by 2012, nations should develop networks of marine protected areas, improve watershed planning and proper coastal land use, eliminate destructive fishing practices, and integrate marine and coastal area management.

What is needed most urgently, says Pauly, is to decommission a large segment of the world's fishing fleet. Moreover, fishery regulations must use the "precautionary approach" of limiting catches in the face of uncertainty about fish populations. The FAO Code of Conduct for Responsible Fishing and the WSSD include language that supports that priority. But these international agreements are only voluntary, and "the political will to implement them has been lacking," Pauly says. Few nations have been willing to risk disrupting fishermen's livelihood.

Some areas have successfully limited access to fishing grounds without ruining career fishermen. Fishery managers can set harvest limits in tandem with quotas that allow individuals in a particular fishery to catch a certain amount. "Individual fishing quotas" (IFQs) can then be traded. New Zealand, for example, has established IFQ programs, as have some U.S. fishery councils. IFQs are a way to reduce the number of vessels through a market mechanism rather than through fishery collapses or government buyouts of vessels. In a traditionally managed fishery, many fishermen go bankrupt if the fishery collapses. But under an IFQ system, access is limited to those who buy shares, and fishermen who want to get out of commercial fishing can sell their shares, allowing other fishermen to expand their operations. However, in 1996 Congress set a moratorium on further U.S. IFQ programs, in the fear that such programs would allow large industrial fishing interests to buy up all the shares in a fishery and drive small fishermen out of business.

Scientists and policy analysts agree that the era of overcapitalized commercial fishing fleets must end. Some coastal communities and nations will probably soon face a long, difficult transition to smaller fleets, which could lead to more sustainable harvests. Coastal nations will have to manage fisheries more rigorously, gain better information about fishery stocks, and control pollution going into coastal waters. Meanwhile, marine aquaculture must address pollution and fish-for-food controversies, experts say. The developing world, in particular, is growing increasingly dependent on the ocean for animal protein. And in wealthier countries, consumers clamor for meals of shrimp and salmon as a healthy alternative to meat. The ocean, as a result, could continue to be hard-pressed to meet all of the demands of a world hungry for seafood.

Fighting on behalf of fish. The U.S. Coast Guard fights illegal fishing both domestically (left) and in tandem with international governments (above, where the Coast Guard cutter at top turns the detained Chinese fishing vessel at right over to the Chinese authorities at left). However, international treaties are seen as being largely ineffective at preventing piracy of valuable species.

John Tibbetts

Editor's note: "The State of the Oceans, Part 2: Delving Deeper into the Sea's Bounty" appears in our June 2004 issue [*EHP* 112:A472–A481 (2004)].